# IMPACT OF IRON ORE MINING ON WATER QUALITY

A THESIS SUBMITTED IN PARTIAL FULLFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

**Bachelor of Technology**

**In**

**Mining Engineering**

By

**ABINASH NAIK**

111MN0395

**DEPARTMENT OF MINING ENGINEERING**
**NATIONAL INSTITUTE OF TECHNOLOGY**
**ROURKELA – 769008**

**2014-2015**

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**Under the guidance of**

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## National Institute of Technology, Rourkela

# CERTIFICATE

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This is to certify that the thesis entitled **"Impact of iron ore mining on water quality"** submitted by Sri Abinash Naik (Roll No. 111MN0395) in partial fulfilment of the requirements for the award of Bachelor of Technology degree in Mining Engineering at the National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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# ABSTRACT

Mining operations require water for their functioning directly and indirectly. Since a long time mining industry has been exploiting water without realizing the adverse impact it is having on the environment and the regional ecosystem. Acid mine drainage has become a major concern associated with mining. Water contamination has caused spread of many diseases and has caused loss of life. This situation requires to be addressed before damaging the environment more and risking the ecosystem with it. Analysis of water quality for all the water bodies around the mines must be done to determine the source, effect and remedies of the pollutants and contaminants. This study deals with the analysis of water sample collected from iron ore mines. Similar work has been carried out by Ghosh and Sen (1999).

*Sampling*

Samples of water were collected from iron ore mining areas of Tensa region of Sundargarh district. One sample was also collected from Kiriburu iron ore mines of SAIL. The analysis was carried out to determine the effect of iron ore mining on the water quality of the nearby areas of the mine. The purpose was also to have a comparative study of the effects on the water quality of the two different mines from different regions. Water samples were tested for parameters like DO, BOD, Conductivity, pH, Chlorides, Hardness and heavy metals.

*Experimental*

Uses of water like irrigation, drinking, recreation, fishing and watering stock are dependent on water quality suitable for them. Ecological processes are sustained by water quality. Apart from farming, fishing and other domestic uses, water is also used for drinking purposes by both humans and other living organisms. This makes it important to measure the water quality time to time in order to maintain the quality else the environment will suffer.

The water quality parameters were determined using the standard methods (APHA, 2012). Multi Parameter Water Quality Analyzer was used for testing of the parameters, DO, pH, conductivity, salinity, ORP whereas Atomic Absorption Spectroscopy was used for determination of metal concentration. Chlorides and hardness were determined by titration. Water Quality Index was calculated using weighted arithmetic index method (Brown et al.) by the designed software.

Some of the important parameters and the water quality index of the five samples have been presented below:

| Sample nos. | Parameter<br>All parameters in mg/L except conductivity (μS/cm) and pH. | | | | | | | | WQI |
|---|---|---|---|---|---|---|---|---|---|
| | pH | DO | BOD | TDS | Alkalinity | Hardness | Conductivity | Chlorides | |
| Sample-1 | 5.59 | 8.14 | 0.56 | 0.018 | 59 | 106 | 0.027 | 7.09 | 26.69 |
| Sample-2 | 5.89 | 8.3 | 0.82 | 0.018 | 64 | 158 | 0.028 | 7.65 | 25.616 |
| Sample-3 | 6.04 | 6.56 | 0.52 | 0.024 | 62 | 178 | 0.037 | 7.65 | 29.76 |
| Sample-4 | 6.21 | 7.42 | 0.34 | 0.148 | 48 | 124 | 0.0227 | 9.64 | 24.925 |
| Sample-5 | 6.85 | 11.3 | 0.38 | 0.158 | 45 | 76 | 0.62 | 6.94 | 17.66 |

*Conclusion*

Most of the parameters were found to be within the permissible limits. pH of the samples were found to be below the standard limit and iron content of sample-3 was found to be more than desired limit. Chromium content of four samples were found to be more than the threshold limits. Both the tap water sample were of excellent water quality whereas the surface water samples were found to be of good water quality.

*References*


Brown R.M., McCeiland N.J, Deininger R.A, 1970 “Water quality index-do we dare?”, Water Sewage Works, Vol-117(10), pp: 339-343

Ghose M.K and Sen P.K, 1999, “Impact on Surface Water Quality due to the Disposal of Tailings from Iron Ore Mines in India”, Journal of Scientific & Industrial Research, Vol-58, September 1999, pp: 699-704.

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# CHAPTER -1

# INTRODUCTION

# 1. INTRODUCTION

Water pollution is a substantial issue of the world which requires periodic assessment and amendment of water asset strategies at all levels. Water pollution is heading overall reason for deaths and diseases. According to the World Health Organization, such diseases account for an estimated 4.1% of the total disability-adjusted life year (DALY) global burden of disease, and cause about 1.8 million human deaths annually with unsafe water supply, sanitation and hygiene being the measure causes. Water contamination is an intense issue in both developed and developing countries who keep on struggling in this issue.

Water is typically referred to as polluted when it is impaired by anthropogenic contaminants and either does not support a human use, such as drinking water, or undergoes a marked shift in its ability to support its constituent biotic communities, such as fish. Natural phenomena such as volcanoes, algae blooms, storms, and earthquakes also cause major changes in water quality and the ecological status of water. The specific contaminants leading to pollution in water include a wide spectrum of chemicals, pathogens, and physical changes such as elevated temperature and discoloration. While many of the chemicals and substances that are regulated may be naturally occurring (calcium, sodium, iron, manganese, etc.) the concentration is often the key in determining what is a natural component of water and what is a contaminant. High concentrations of naturally occurring substances can have negative impacts on aquatic flora and fauna.

The first step towards controlling water pollution is to know its causes and effects. Once the causes are known proper mitigation steps can be taken to control these factors. It is also essential to study the impacts of pollution on water quality. We need to know how water quality is affected due to all these factors and how will the water quality affect life and operations. For that the different essential physical and chemical parameters need to be studied.

Mining is one of the major causes of water pollution. Mining activities are also responsible for many other shares of environment degradation. Main sources of water pollution from mines are mine water drainage, flow or leakage of mineral exposed water to the water sources nearby, acid mine drainage and water from spoil heaps. These sources also result in pollution viz. heavy metal contamination and leaching, erosion and sedimentation. Even tailings from the mineral processing plants affect the surface and ground water quality.

### 1.1 *Objective of the study*

Keeping the major problem of water contamination due to mining activities in mind the broad objectives of this study has been outlined as:

1. Studying the impact of iron ore mining on water quality.
2. Collect and analyze different water samples for essential physical and chemical parameters.
3. Identify the undesired components and their sources.
4. Develop a calculator to calculate the Water Quality Index of the samples and determine quality of water from it.

# CHAPTER-2

# LITERATURE REVIEW

# 2. LITERATURE REVIEW

**Singh (1997)** conducted a number of tests and concluded that the prime reasons of water contamination in mines are pollution due to the mine water effluents being discharged into water ,leaching from the wash-off dumps, toxic wastes from solid waste disposal sites, broken rocks, acid mine drainage etc. He suggested some mitigation methods like, overburden run-off water collection and treating it with sediment control, collection of leachates, seepages, wash-offs with subsequent treatment, Oil and grease separators, proper sanitation , provision for sewage and effluent treatment, treatment of mine water discharges etc.

**Ghosh and Sen (1999)** attempted to assess the impact due to disposal of tailings from iron ore mines of SAIL on surface water quality at Bolani, Sundargarh. Four samples were collected from the river, one on upstream, one at confluence point and two on downstream side of the effluent discharge point. Temperature, pH and DO were measured on site where as Fe, Mn, Al, Cu and Zn were analyzed by AAS. Cr, Mo, Ni and Co were measured by ICP. A higher concentration of iron in comparison to Indian norms were found. Pollutant contribution to the surface water bodies through tailing ponds were more prominent in terms of Fe, Mn and suspended solids. Thy suggested treatment of process water for removal of iron, suspended solids and other contaminants.

**Razo et al. (2002)** attempted to assess the impacts of mining on soil, sediment and surface water in the Villa de la Paz-Matehuala area. Surface water samples were collected from small ponds or basins where fluvial water is stored. The arsenic concentration in water storage ponds and stream sediments decreased as distance increased from potential sources. Highest Arsenic concentration was found to be 100 times more than the established limit. The results suggest that the fluvial transportation of mine waste through streams that cross the area and Aeolian transportation of mineral particles are mainly associated with dispersion of arsenic and heavy metals from their sources.

**Lupankwa et al. (2003)** investigated the impact of the slimes on the surrounding ground and surface water. Surface water samples were collected from 12 sites around the slimes dam. The samples were analyzed for dissolved metals using AAS and for anions using gravimetric and titration. The analysis showed release of acidic effluent with high concentration of Fe, Ni and

$SO_4$ from the tailing dam. Concentration of metals was found to be low after the water had passed through the natural wetlands. Analysis of ground water showed similar high levels of acidity, Sulfate and metal. These findings show that acid mine drainage is seeping from the tailings dam.

**Qian et al. (2007)** evaluated water quality of surface sources by multivariate methods. They also used a new WQI in Indian River lagoon, Florida. They put six stations at six different locations and monitored them continuously. Clustering method was used to cluster the six monitoring stations in groups of 2 with characteristically similar and same stations in the same group. They carried out evaluation of the two groups and determined the results of water quality.

**Ramakrishnaiah and Ranganna (2009)** evaluated WQI of ground water samples from Tumkur Taluk in Karnatka. They gathered the samples and did a physiochemical analysis of the specimens. The considered 12 parameters, viz. hardness, pH, calcium, bicarbonates, magnesium, chlorides, sulfates, total dissolved solids, manganese, iron and fluorides. The water quality index of the samples ranged from 89.21 to 660.56. This analysis concluded that the ground water of the place required some level of treatment before utilization and it additionally needed to be protected from the danger of consumption.

**Cherry et al. (2009)** conducted an assessment of water sheds which are impacted by mines of south-western Virginia, USA. The study was carried out to inspect the use of integrative bio-assessment. Twenty samples were selected for study. Markson field pH meter was used to measure pH while conductivity was measured by Hach portable conductivity meter. Parameters included in study were water column chemistry, chronic sediment toxicity, sediment metal chemistry and Eco-toxicological rating (ETR).The study found that when pH was below 3 consistently, in-situ microorganisms are few. Sites ranged from 3.5 to 6.0 had acid mine drainage. The study illustrated that the effect of environmental stress was showed by abiotic sampling procedures.

**Verma et al. (2010)** studied the effect of overburden on water environment and their leaching levels at Chira mines of Singhbum, Jharkhand. Seven samples were collected from Koina River and Koel River. A near neutral to marginally alkaline pH was observed. Koina River samples showed higher turbidity. The concentration of toxic metals was below water quality standards. The water was found to be good for irrigation purpose as all values were within the tolerance limits. The observations on phytoplankton community in streams and rivers also showed good biodiversity.

**Ameh E.G et al. (2011)** studied the impact of iron-ore mining by using heavy metal pollution indexing and multivariate statistical evaluation of hydro-geochemistry of river PovPov in Itakpe iron-ore mining area, Nigeria. 13 samples were collected. Sampling was done randomly but evenly distributed from upstream to downstream sections of the river. Spectrophotometer (Genesys 20) was used to determine the concentrations of Mg, Na, Ca, K, $NO_3$ and $SO_4$. AAS (210 VGP) was used for determination of concentration of Pb, Zn, Ni, Cd, Cu and Fe. Heavy Metal Pollution Index (HPI) and Metal Index (MI) approaches were used for data evaluation. Univariate and Multivariate statistical methods of analysis were also used for statistical analysis along with SPSS 11.0. The HPI calculated with mean values of all six heavy metals were far above the critical index values.

**Jayaraju et al. (2014)** attempted to measure pollution impact of iron ore tailings as responded by foraminiferal species. The area of study was the Nellore coast line famous for iron ore export. 14 bottom sediment samples were taken from different sites and analyzed. The result showed substantial reduction in total foraminiferal number (TFN) and total species number (TSN). These numbers were inversely related to the total suspended solids in water. The foraminiferal fauna has almost disappeared from the disposable area of iron ore. The study also found that there has been decline in TSN and TFN after the export of iron ore began from the Krishnapatnam port.

# CHAPTER-3

# IMPACT OF IRON ORE MINING ON WATER QUALITY

# 3. IMPACT OF IRON ORE MINING ON WATER QUALITY

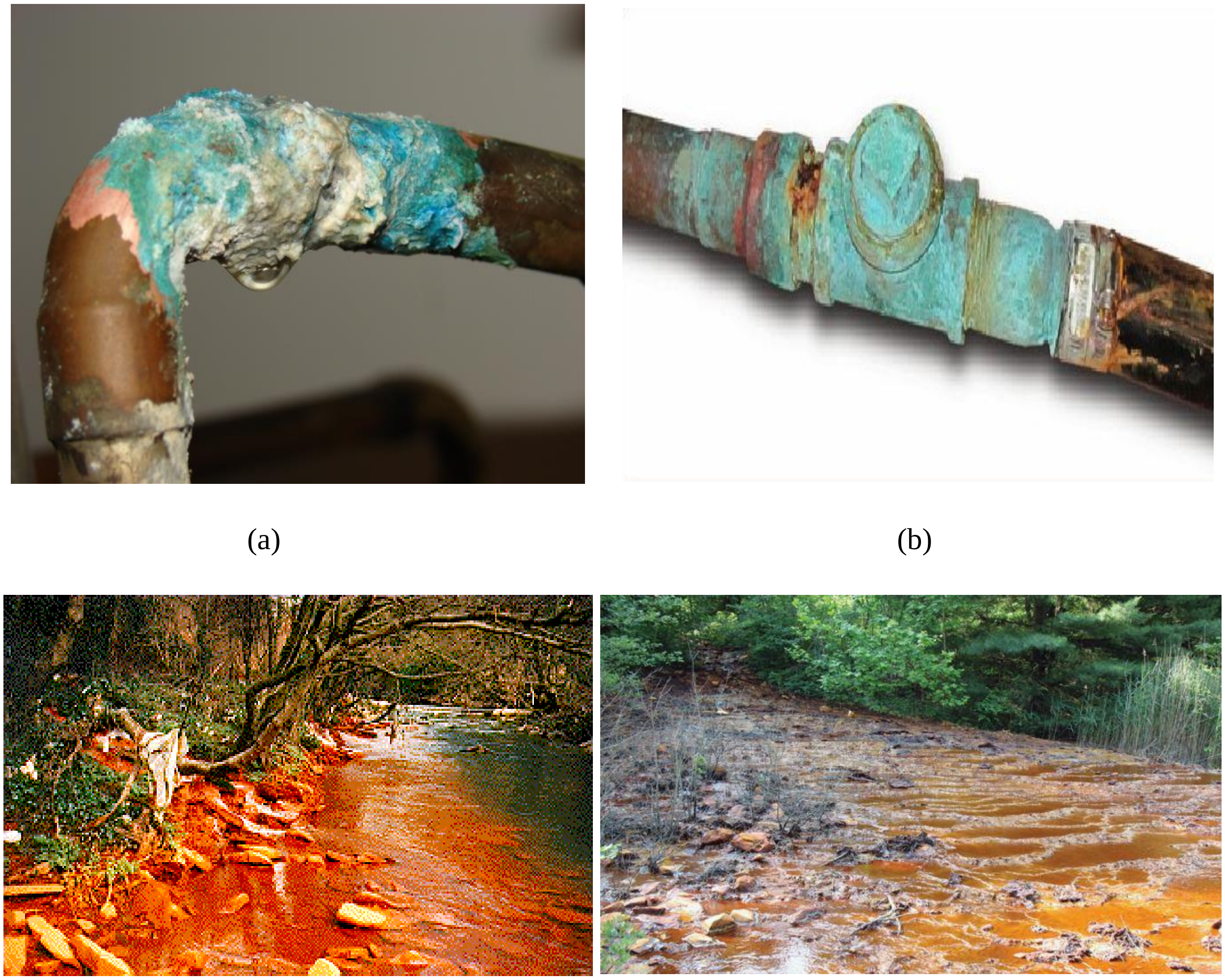
Mining operation causes many adverse impacts on environment due to the extractive nature of the operations. The extent of the impact and its nature can range from significant to minimal depending up on a range of factors associated with the mine. Generally these impacts are confined to local areas.

For operations like mineral processing, metal recovery, dust control and meeting the requirements of workers on site water is needed in mines. The amount of water needed varies depending on mine size, mineral being extracted and the process used for extraction.

### 3.1 *Water Quality is affected by*

- Sulfide minerals present in excavated rocks which are present in large quantities interact with oxygen and water to form acids. Due to these acids in water the pH of water is reduced and as it flows it dissolves more and more metals in it resulting in a very toxic and low pH water.
- Naturally occurring heavy metals often get released in to the mineral extraction process. Metals like Co, As, Cd, Hg, Cu, Pb, Zn etc. are contained in the rock may leach out and get carried downstream by water.
- Chemical agents like CN and $H_2SO_4$ from the mining site get spilled, leached or leaked in to nearby water bodies.
- Water present closer to mining locations have high hardness values due to mining activities.
- Alongside hardness, surface water polluted by mine seepage generally has higher pH and lower acidity, aggregate iron, manganese, aluminum, and suspended solids than untreated surface mine waste.

Photographs of the some of the impacts have been presented in Figure 3.1. These impacts are not limited to current mining operations. Mining residues and scraps at old mining sites may also impact on local environment. These impacts must be kept under control. For that it is necessary to analyze the water quality periodically.



(a) (b)

(c) (d)

Fig 3.1: Different effects of water pollution: (a) and (b) corrosion of pipes, (c) and (d) acid mine drainage. (Source: http://www.flcorrosioncontrol.com/)

***3.2 Health Impacts***

A. Waterborne diseases caused by polluted water

1. Rashes, ear ache, pink eye
2. Respiratory infections
3. Hepatitis, encephalitis, gastroenteritis, diarrhoea, vomiting, and stomach aches

B. Conditions related to water polluted by chemicals (persistent organic pollutants, heavy metals)

    1. Cancer including prostate cancer and non-Hodgkin's lymphoma
    2. Hormonal problems that can disrupt reproductive and developmental processes
    3. Damage to the nervous system
    4. Liver and kidney damage
    5. Damage to the DNA
    6. Exposure to mercury (heavy metal)
        - In the womb: may cause neurological problems including slower reflexes, learning deficits, delayed or incomplete mental development, autism and brain damage
        - In adults: Parkinson's disease, multiple sclerosis, Alzheimer's disease, heart disease, and even death

# CHAPTER-4

# SAMPLING AND WATER QUALITY ANALYSIS

# 4. SAMPLING AND WATER QUALITY ANALYSIS

## 4.1 *Sampling*

In order to obtain representative samples sampling is carried out. These samples should mirror the environment and surrounding conditions in which it is present that is, in the surrounding area the concentration should be similar to that of the sample taken. The area should also be so selected that the mining activities and operations of that place is reflected by it. The water bodies from which samples are taken should be within confines of mining area and not isolated.

The collected samples should be handled carefully to avoid any significant changes taking place between the time collecting the samples and analysis in lab. To ensure this the samples should be stored in laboratories in proper preserving conditions. The collection of samples should be pre planned and must be consulted prior to collection to obtain accurate results.

## 4.2 *Basic guidelines for sampling*

- Samples are obtained as per the program in such a way that it doesn't get contaminated before analyzing it.
- The equipment used for sampling must be clean, free of pollutants and reliable before use.
- The sample should not be pre rinsed because it causes in loss of preservatives which might be pre added.
- Special precautions should be taken for those samples which contain organic compound and trace metals as they are present in very small concentration.
- There is no applicable recommendation universally for the composite samples as it can vary with time, place and depth depending on the surrounding condition. So these samples can be collected as applicable.
- To determine the metal content it is highly recommended to add ultrapure acid to the samples to prevent precipitation of metals and contamination by bringing the pH down below 2.

### 4.2 *Sample Collection*

All the samples were collected from iron-ore mining areas of Tensa region of Sundargarh district and Kiriburu mines of SAIL. Surface-water and daily use tap water samples were collected to analyze. For each sample, two 1-litre bottles were used.

Table 4.1: Sample name and respective locations of them

| Sample Name | Place | Coordinates |
|---|---|---|
| **Sample -1** | Tehrai Nala, Koida region | N21º54’ E85º17’35.2” |
| **Sample-2** | Bandal Mn Mines | N21º54’ E85º12’38.2” |
| **Sample-3** | No. 3 Check dam, JSPL | N21º53’09” E85º10’20.3” |
| **Sample-4** | Tap water, JSPL, Tensa | N21º52’36” E85º53’59.6” |
| **Sample-5** | Tap water, Kiriburu, SAIL | N 22.1083° E 85.2951° |

Fig 4.1: Location of Sample-1

Fig 4.2: Location of Sample-2

Fig 4.3: Location of Sample-3

Fig 4.4: Location of Sample-4

**4.3 *Water Quality Analysis***

Quality of water is defined by its physical, chemical and biological characteristics. It is considered as a measure of condition of water so as to the requirement of different species of the eco system. Water quality must support a rich and wide-ranging community of organisms and must not harm public health in a healthy environment. Uses of water like irrigation, drinking, recreation, fishing and watering stock are dependent on water quality suitable for them. Ecological processes are sustained by water quality.

Apart from farming, fishing and other domestic uses, water is also used for drinking purposes by both humans and other living organisms. This makes it important to measure the water quality time to time in order to maintain the quality else the environment will suffer.

Water quality can be measured by analyzing it for different physical and chemical parameters of it. Different parameters have different methods of analysis. Each parameter is compared with the standards specified by different agencies to determine whether the water is suitable for use or not.

Table 4.2: Physical Parameters

| | Parameters | Method of analysis |
|---|---|---|
| Physical Parameter | Temperature | Multi Parameter Water Quality Analyzer |
| | Conductivity | Multi Parameter Water Quality Analyzer |
| | Turbidity | Multi Parameter Water Quality Analyzer |
| | Total Dissolved Solids | Multi Parameter Water Quality Analyzer |

Table 4.3: Chemical Parameters

| | Parameter | Method of Analysis |
|---|---|---|
| Chemical Parameters | pH | Multi Parameter Water Quality Analyzer |
| | Dissolved Oxygen | -do- |
| | Salinity | -do- |
| | Oxidation Reduction potential | -do- |
| | BOD | Titrimetric Method |
| | Nitrate | Colorimeter |
| | Chloride | Titration with $AgNO_3$ |
| | Sulphate | Turbidimetric method |
| | Hardness | EDTA Titration |
| | Metals(Fe, Zn, Cu, Cr, As, Pb, Ni) | AAS |
| | Metal ions ($Na^+$, $K^+$) | Flame Photometry |

### 4.4 *Parameters and their significance*

***pH:*** It is the measure of the $H^+$ ions present in water. It can be any value in between 0 to 14. For acidic water the value lies within 0 to 7 whereas for basic water it lies in between 7 to 14. The lesser the value of pH the more acidic the water is and the more the value of pH the more is the alkalinity of it.

pH affects the solubility of water and also it governs the amount of nutrients dissolved in water. This affects how water is used by aquatic animals. The more acidic the water, more is the chances of dissolving heavy metals. pH must lie within 6.5 to 8.5 for drinking water as per the standards.

***Dissolved Oxygen:*** It is the amount of oxygen dissolved in water. It can be measured in mg/L or expressed in % of dissolved oxygen. The dissolved oxygen is utilized by the aquatic life. Hence the amount of dissolved Oxygen must be sufficient for sustaining the life under water. Dissolved oxygen varies inversely with temperature. The lower the temperature more is the ability of water to dissolve oxygen.

***Biochemical Oxygen Demand (BOD):*** It is the measure of how much of $O_2$ is utilized by microbes for aerobic oxidation and breaking down of organic matter present in water. More is the BOD, less is the availability of $O_2$ for aquatic life and more is the organic matter present in it. It is measured for a period of 5 days and expressed in mg/L. It should be less than 5mg/l as per drinking water standards.

***Conductivity:*** Conductivity of water is an indirect measure of ion concentration of the solution. More is the ions concentration more will be the conductivity. Ions like Na+, $Mg^2$+, K+, $Ca^2$+ etc. increase the conductivity. The conductivity is measured in μS/cm at 25ºC and should be within 0 to 70.

***Total Dissolved Solid (TDS):*** It is a measure of the amount of particulate solids that are present in the solution. TDS is an indicator of pollution problems associated with land use practices. TDS is directly proportional to conductivity and conductivity is used to measure TDS indirectly. More TDS results in hardening of water. It also causes corrosion pf pipes that it flows in. It creates a salty and bitter taste of water. It is measured in mg/L.

***Turbidity:*** Turbidity is a measure of the clarity of water. The more the amount of suspended (organic or mineral) solids, more is the turbidity. It is a measure of the light scattering properties of water. Sediments from human construction can runoff with water to cause turbid conditions. Quarrying and mining operations also result in turbid water due to colloidal rock particles. High turbidity can inhibit the effect of disinfection against microbes and enables bacterial growth. Turbidity is measured in NTU and must be less than 10 for drinking water.

***Hardness:*** Hardness in water is caused by the dissolved Calcium and Magnesium salts which get dissolved in water from soil or minerals containing limestone or dolomite. If hardness is found to be more than 300 mg/L then the water is hard and for less than 70 mg/L it is soft. Hard water can cause scaling in utensils and makes it difficult for foam creation hence causes use of more soap and detergent. It should be less than 300 mg/L in drinking water.

***Iron:*** Iron content in water can result from leaching of iron pipes in water distribution system. Also near iron ore mining areas, iron tailings can enter into surface runoff water. Presence of iron in water can cause bitter and metallic taste of water. It can cause brownish green stains in clothes, blackening of water with rusty sediments and discoloring of beverages. Iron content should be less than 0.3 mg/L.

***Chloride:*** Chloride content of water can increase if it comes in contact with fertilizers and Industrial wastes. Chloride can also result from sea water and different minerals. Presence of chloride more than the permissible limit of 250 mg/L can cause health effects like high blood Pressure. It also causes salty taste of water, corrosion of pipes and blackening of stainless steel.

***Arsenic:*** Arsenic enters into water through different pesticides, glass or electronic wastes which are not disposed properly and from natural sources like rocks. Presence of arsenic more than the permissible limit of 0.05 mg/L can cause weight loss and make water toxic to skin and nervous system.

***Chromium:*** Chromium enters into water from industrial and mining wastes. High concentration of chromium can cause skin and nasal ulcer. It can cause adverse health effects like lung tumors, gastro-intestinal damage and nervous system damage. It can also accumulate in spleen, kidney and liver causing complications. It should always be less than 0.1mg/L in drinking water.

***Copper:*** Copper enters into water through leeching from copper tubes, industrial and mining wastes. High copper concentration causes health effects like Anemia, digestive disturbance, liver and kidney damages and gastro-intestinal irritation. It also causes bitter and metallic taste of water and staining of clothes. Copper concentration should be less than 0.05 mg/L in drinking water.

***Cyanide:*** Cyanide sources in water are fertilizers, electronic wastes, steel, plastic and mining wastes and some natural sources. Cyanide is very poisonous and can cause nervous damages and thyroid problems. The concentration of CN must be less than 0.05 mg/L in drinking water.

***Lead:*** The major sources of lead are paints, diesel fuel, batteries, pipes and solder. Lead also occurs naturally and can enter water from any of these sources. Lead can cause metal poisoning and other adverse health effects like mental retardation, kidney and neurological damages, hearing loss, blood disorders and even death at higher concentration. Lead should be less than 0.05 mg/L in water to make it suitable for drinking.

***Mercury:*** Mercury enters water through pesticides, fungicides, batteries, paints, and electrical wastes. Mercury can cause vision and hearing loss, intellectual deterioration and many other health effects if found in high concentration. It should be present at a concentration below 0.001mg/L.

## 4.5 *Procedures to analyze water quality parameters*

### 4.5.1 *Multiparameter Water Quality Analyzer*

This device helps to indicate and measure the monitoring results of up to 11 parameters with one unit. It is very user friendly and can be used on site for monitoring. It is used to check the quality of river water, ground water, drainage water etc.

Table 4.4: Range of Multiparameter Water Quality Analyzer for different parameters

| Parameters | Range |
|---|---|
| **Temperature** | -10ºC to 55º C |
| **Conductivity** | 0 to 10 mS/cm |
| **Turbidity** | 0 to 1000 NTU |

| | |
|---|---|
| **Total Dissolved Solids** | 0 to 100g/L |
| **pH** | 0 to 14 |
| **Dissolved Oxygen** | 0 to 50 mg/L |
| **Salinity** | 0 to 70 PPT |
| **Oxidation Reduction potential** | -2000mv to 2000mv |


Fig 4.5: HORIBA Multiparameter Water Quality Analyzer

Calibration

1) The sensor guard is detached and the sensor probe is cleaned with distilled water.
2) The transparent calibration cup is removed.
3) The calibration cup is filled with a pH 4 standard solution.
4) The option of auto calibration under CAL is selected and the sensor is dipped into the standard solution present in the calibration cup.
5) The black calibration cup is placed over the transparent cup and the ENTER key is pressed to begin calibration after all the values have been stabilized.

Procedure

1) The sensors are checked and cleaned with distilled water.
2) The option "SINGLE MEASUREMENT" is selected.
3) The sensor is then dipped into the sample such that no air bubbles remain around the sensor.
4) Once the readings have stabilized, the MEAS key is pressed to acquire the 5- second average.
5) The measurement is saved by pressing the ENTER key.

4.5.2 *Atomic Absorption Spectrometer*

Apparatus

1) Atomic absorption spectrometer
2) Burner
3) Lamps
4) Pressure reducing valves
5) Vent

Procedure

1) The apparatus is set and adjusted according to manufacturer's guidelines.
2) Flame is generated using acetylene and stabilized.
3) Calibrate the apparatus by aspirating the blank solution containing the same amount of acid as in the standards and samples.

| Element | Standards |
| --- | --- |
| **Fe** | 1ppm, 2ppm, 3ppm |
| **Zn** | 0.5ppm, 1ppm, 2ppm |
| **Ni** | 2ppm, 4ppm, 6ppm |
| **Pb** | 1ppm, 2ppm, 3ppm |
| **Cu** | 1ppm, 2ppm, 3ppm |

4) At least 3 standards are aspirated and their absorbance are measured.
5) The samples are then aspirated in the flame, their absorbance measured and the concentrations are calculated and displayed on the screen.

Fig 4.6: Atomic absorption spectrometer

4.5.3 *Flame Photometry*


Fig 4.7: ESICO Microprocessor Flame Photometer

Like the AAS, it does not require any light beam in order to measure the element's concentration. It measures directly the emitted wavelength generated due to the transition of atoms from ground to excited state. No lamp is required like that of AAS to excite the atoms.

A jet of compressed gas is used to convert solution to an aerosol form which is atomized by the flame. The metal constituents of the sample are converted to gaseous atoms which in the process of atomization. These atoms are then ionized. Electrons get excited to higher energy state absorbing the energy from the heat of the flame. While returning to ground state, each metal emits light of a specific wavelength which is detected and used to measure the concentration of the metals.

Procedure

- Distilled water is used as blank initially.
- The calibration of the instrument is with at least 3 standards as mentioned below.

| Element | Standards | Range |
|---|---|---|
| Na | 1ppm, 10ppm, 20ppm | 0.1 to 100 ppm |
| K | 1ppm,5ppm,10ppm | 0.1 to 100 ppm |

- The samples are then aspirated to get the concentration of different parameters.

4.5.4 *Titrimetric method for BOD estimation*

Equipment and Reagents

- BOD bottles of 300ml capacity
- BOD incubator controlled at 20ºC.
- Phosphate Buffer
- $MgSO_4$
- $CaCl_2$
- $NaSO_4$ solution
- Acid and Alkali Solution
- Nitrification inhibitors
- Ferric Chloride

Procedure

- The sample is neutralized to pH 7.
- 50 ml of sample is taken and acidified with addition of 10ml of acetic acid.
- The samples are brought to 20ºC before making dilution.
- The sample, diluted or undiluted, is siphoned in to 3 labeled bottles.
- One bottle is used to determine initial DO and rest 2 are incubated at 20ºC for 3 days.
- BOD of seed blank is determined for correction of actual BOD.
- DO of the samples can be determined using the multi water quality analyzer.

Calculation

BOD of the sample is calculated as follows:

a) When dilution water is not seeded

$$\text{BOD as O2 mg/L} = \{(D1 - D2) \times 100\} / \%\ \text{dilution}$$

b) When dilution is seeded

$$\text{BOD } O_2 \text{ mg/L} = \{(D1 – D2) – (B1 – B2) \times 100\} / \% \text{ dilution}$$

Where,

D1 = DO of sample immediately after preparation, mg/L

D2 = DO of sample after incubation period, mg/L

B1 = DO of blank (seeded dilution water) before incubation, mg/L

B2 = DO of blank (seeded dilution water) after incubation, mg/L

4.5.5 *Hardness (EDTA titration)*

Chemicals Required:

1. Buffer Solution
2. NaOH 2N
3. EDTA
4. Erichrome Black T(EBT) Indicator
5. Standard Calcium Solution

Procedure:

1) Pipette out 20 ml of the sample and add 2ml of Ammonia buffer and then add 1 ml of the inhibitors in it.
2) Add 2 drops of EBT as the solution turns in to red-wine color.
3) Titrate with EDTA solution till the red wine solution turns steel blue.
4) Hardness is calculated as:

$$\text{Ca Hardness} = \frac{(\textbf{Vol. of EDTA})*\textbf{N}*(\textbf{Equivalent Wt.of CaCO3})*\textbf{1000}}{\textbf{Vol. of Sample taken}}$$

Where, N = Normality of EDTA

### 4.5.6 *Chloride ($AgNO_3$ titration)*

Chloride is determined in a neutral or slightly alkaline solution by titration with standard $AgNO_3$ using potassium chromate as indicator.

$Ag^+ + Cl^- \longrightarrow AgCl$ (White precipitate)

$2Ag^+ + CrO_4^{2-} \longrightarrow Ag_2CrO_4$ (Red Precipitate)

Chemicals:

1. $AgNO_3$ (0.02N)
2. Phenolphthalein Indicator
3. Sodium Chloride
4. Potassium Chromate

Procedure:

1. 20 ml of the sample is pipetted out in to a 250 ml flask and 2 drops of $K_2CrO_4$ indicator is dropped in to the sample.
2. It is the titrated with standard $AgNO_3$ solution (0.02 N) till $AgCrO_4$ starts precipitating as pale red precipitate.
3. Chloride concentration is calculated by:

   (A-B) x N x 35.45 x1000 /ml sample, Where , N= normality of $AgNO_3$ used

   A = ml of $AgNO_3$ required for sample, B = ml of $AgNO_3$ required for blank.

## 4.6 *Observations*

Table 4.5: Results from analysis of samples in laboratory

| Parameters | Permissible limits | S-1 | S-2 | S-3 | S-4 | S-5 |
|---|---|---|---|---|---|---|
| **Temperature (°C)** | Shouldn't exceed 5°C above Source | 30.87 | 30.41 | 30.25 | 30.84 | 20.2 |
| **pH** | 6.5-8.5 | ***5.59** | **5.89** | **6.04** | **6.21** | 6.85 |
| **Oxidation Reduction Potential (mV)** | no standards | 268 | 248 | 278 | 298 | 268 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Conductivity (mS/cm)** | 0.3 | 0.027 | 0.028 | 0.037 | 0.0227 | 0.62 |
| **Turbidity (NTU)** | 10 | 9.3 | 18.3 | 2.4 | **10** | **20** |
| **Dissolved Oxygen (mg/L)** | >5 | 8.14 | 8.3 | 6.56 | 7.42 | 11.3 |
| **Dissolved Oxygen (%)** | NA | 109.5 | 111.1 | 87.4 | 99.8 | 132.6 |
| **Total Dissolved Solid (g/L)** | 0.5 | 0.018 | 0.018 | 0.024 | 0.148 | 0.158 |
| **Salinity(ppt)** | NA | 0 | 0 | 0 | 0.1 | 0.2 |
| **BOD** | 2(3days) | 0.56 | 0.82 | 0.52 | 0.34 | 0.38 |
| **Alkalinity(mg/L)** | 120 | 59 | 64 | 62 | 48 | 45 |
| **Chloride (mg/L)** | 250 | 7.09 | 7.65 | 7.65 | 9.64 | 6.94 |
| **Hardness (mg/L)** | 300 | 106 | 158 | 178 | 124 | 76 |
| **Sodium (mg/L)** | 50 | 0.17 | 0.46 | 0.77 | 0.58 | 0.27 |
| **Potassium (mg/L)** | NA | 0.09 | 0.16 | 0.23 | 0.12 | 6.11 |
| **Iron (mg/L)** | 0.3 | 0.189 | 0.145 | **0.32** | 0.1 | 0.12 |
| **Zinc (mg/L)** | 5 | 0.018 | 0.107 | 0.007 | 0.006 | 0.002 |
| **Nickel (mg/L)** | 0.02 | 0.021 | 0.018 | 0.014 | 0.002 | 0.012 |
| **Lead (mg/L)** | 0.1 | **BDL | BDL | 0.002 | 0 | 0 |
| **Mercury (mg/L)** | 0.001 | BDL | BDL | BDL | BDL | BDL |
| **Chromium (mg/L)** | 0.1 | **0.226** | **0.332** | **0.22** | 0 | 0 |
| **Arsenic (mg/L)** | 0.05 | 0.022 | 0.021 | 0.028 | 0.031 | 0 |
| **Cadmium (mg/L)** | 0.01 | 0.003 | 0.003 | 0.004 | 0.006 | 0.001 |
| **Copper (mg/L)** | 0.05 | BDL | BDL | BDL | BDL | BDL |

### 4.7 *Water Quality Standards*

Drinking water quality standards describe the quality parameters set for drinking water. There is no globally approved and accepted international standard for drinking water. Even at the places where standards are applied, they may vary by as much as 10 times from the set of standards.

Table 4.6: Indian Standard Specifications for Drinking Water (IS: 10500)

| Sl. No | Parameter | Desirable Limit | Remarks |
|---|---|---|---|
| **1** | Colour | 5 | If toxic components suspected then can be relaxed up to 50 |
| **2** | Turbidity | 10 | May be relaxed up to 25 in absence of an alternate source of water |
| **3** | pH | 6.5-8.5 | May be relaxed up to 9 in absence of an alternate source of water |
| **All values in mg/l from No.4 to 28** | | | |
| **4** | Total Hardness | 300 | May be relaxed up to 600 |
| **5** | Calcium as Ca | 75 | May be relaxed up to 200 |
| **6** | Magnesium as Mg | 30 | May be relaxed up to 100 |
| **7** | Cu | 0.05 | May be relaxed up to 1.5 |
| **8** | Fe | 0.3 | May be relaxed up to 1 |
| **9** | Mn | 0.1 | May be relaxed up to 0.5 |
| **10** | Chlorides | 250 | May be relaxed up to 1000 |
| **11** | Sulphates | 150 | May be relaxed up to 400 |
| **12** | Nitrates | 45 | No relaxation |
| **13** | Fluorides | 0.6-1.2 | Below 0.6 undesired. May be extended to 1.5 |
| **14** | Phenols | 0.001 | May be relaxed up to 0.002 |
| **15** | Hg | 0.001 | No relaxation |
| **16** | Cd | 0.01 | No relaxation |
| **17** | Se | 0.01 | No relaxation |
| **18** | As | 0.05 | No relaxation |
| **19** | Cyanide | 0.05 | No relaxation |
| **20** | Pb | 0.1 | No relaxation |
| **21** | Zinc | 5.0 | May be relaxed up to 10 |
| **22** | Anionic Detergents | 0.2 | May be relaxed up to 1 |
| **23** | Chromium as $Cr^{6+}$ | 0.05 | No relaxation |

| | | | |
|---|---|---|---|
| **24** | Mineral oil | 0.01 | May be relaxed up to 0.03 |
| **25** | Residual free Cl | 0.2 | Applicable only when water is chlorinated |
| **26** | Pesticide | Absent | ---- |
| **27** | Boron | 1 | May be relaxed up to 5 |
| **28** | Aluminium as Al | 0.03 | May be relaxed up to 0.2 |
| | | | |

Table 4.7: Standards for Discharge of Environmental Pollutants

| **Standards for Discharge of Environmental Pollutants** | | | | | |
|---|---|---|---|---|---|
| **SL No.** | Parameters | **Standards (All in mg/l except Temperature and pH)** | | | |
| | | Inland Surface Water | Public Sewers | Land of Irrigation | Marine/Coastal Areas |
| **1** | Suspended solids | 100 | 600 | 200 | 100 |
| **2** | Particle size of suspended solids | Shall pass 850µ IS Sieve | - | - | Floatable Solid 3mm, Settlable Solids 856µ |
| **3** | pH | 5.5-9.0 | 5.5-9.0 | 5.5-9.0 | 5.5-9.0 |
| **4** | Temperature | Must not exceed 5ºC above the receiving temperature | - | - | Must not exceed 5ºC above the receiving temperature |
| **5** | Oil and grease | 10 | 20 | 10 | 20 |
| **6** | Total residual chlorine | 1.0 | - | - | 1.0 |
| **7** | Ammonical nitrogen | 50 | 50 | - | 50 |
| **8** | Total nitrogen (as N) | 100 | - | - | 100 |
| **9** | Free ammonia (as NH3) | 5.0 | - | - | 5.0 |
| **10** | BOD 3days | 30 | 350 | 100 | 100 |
| **11** | COD | 250 | - | - | 250 |
| **12** | As | 0.2 | 0.2 | 0.2 | 0.2 |

| | | | | | |
|---|---|---|---|---|---|
| **13** | Hg | 0.01 | 0.01 | - | 0.01 |
| **14** | Pb | 0.1 | 0.1 | - | 2.0 |
| **15** | Cd | 2.0 | 1.0 | - | 2.0 |
| **16** | $Cr^{6+}$ | 0.1 | 2.0 | - | 1.0 |
| **17** | Total chromium | 2.0 | 2.0 | - | 2.0 |
| **18** | Cu | 3.0 | 3.0 | - | 30 |
| **19** | Zn | 5.0 | 15 | - | 15 |
| **20** | CN | 0.2 | 2.0 | 0.2 | 0.2 |
| **21** | F | 2.0 | 15 | - | 15 |
| **22** | Phenolic Compounds | 1.0 | 5.0 | - | 5.0 |
| **23** | Mn | 2 | 2 | 2 | 2 |
| **24** | Fe | 3 | 3 | 3 | 3 |

# CHAPTER-5

# DEVELOPMENT OF WATER QUALITY INDEX CALCULATOR

# 5. DEVELOPMENT OF WATER QUALITY INDEX CALCULATOR

### *5.1 Water Quality Index Calculator*

Water Quality Index is a criterion to determine the quality of water and check the usability of water for various purposes. Basic parameters (given in table 6.1) are used to calculate the index.

WQI (Water Quality Index) is calculated by using the standards of drinking water quality recommended by WHO, BIS and ICMR. The weighted arithmetic index method (**Brown et.al**.) has been used for calculation of WQI of water samples.

Table: 5.1: Drinking water standards, recommending agencies and unit weight

| SL No. | Parameter | Standards | Recommended by | Unit Wight (Wn) |
|---|---|---|---|---|
| **1** | pH | 6.5-8.5 | ICMR/BIS | 0.219 |
| **2** | Electrical Conductivity | 300 | ICMR | 0.371 |
| **3** | Total Dissolved Solid | 500 | ICMR/BIS | 0.0037 |
| **4** | Total Alkalinity | 120 | ICMR | 0.0155 |
| **5** | Total hardness | 300 | ICMR/BIS | 0.0062 |
| **6** | Total Suspended Solids | 500 | WHO | 0.0037 |
| **7** | Calcium | 75 | ICMR/BIS | 0.025 |
| **8** | Magnesium | 30 | ICMR/BIS | 0.061 |
| **9** | Chlorides | 250 | ICMR | 0.0074 |
| **10** | Nitrate | 45 | ICMR/BIS | 0.0412 |
| **11** | Sulphate | 150 | ICMR/BIS | 0.01236 |
| **12** | Dissolved Oxygen | 5 | ICMR/BIS | 0.3723 |
| **13** | BOD | 5 | ICMR | 0.3723 |

### 5.2 *Calculation*

Water quality index is calculated as

$WQI = \quad \Sigma q_n Wn / \Sigma Wn$

Where, $q_n$ = Sub-index or Quality Rating of $n^{th}$ parameter

Wn = Unit weight of the $n^{th}$ parameter obtained from Table 5.1

$q_n = 100 [Vn - V_{i0}] / [Sn - V_{i0}]$

Sn = Standard permissible value of the $n^{th}$ parameter

Vn= Estimated value of the $n^{th}$ parameter

$V_{i0}$= Ideal value of the $n^{th}$ parameter in pure water (0 for all except pH=7.0, DO = 14.6 mg/l)

From the calculated index values the status of water quality can be obtained (**Chatterjee and Raziuddin 2002**) as follows

Table 5.2: Water quality index and quality status

| Water Quality Index | Water Quality Status |
|---|---|
| **0-25** | Excellent Water Quality |
| **26-50** | Good Water Quality |
| **51-75** | Poor Water Quality |
| **76-100** | Very Poor Water Quality |
| **>100** | Unsuitable for Drinking |

### 5.3 *Developing the Calculator*

The method of calculation of WQI by the weighted arithmetic method takes very long time and needs many mathematical calculation and tabulations. The objective of designing the calculator was to make the process of calculation of WQI easy and time saving.

**Microsoft Visual Studio 2013** was used to design the User Interface of the calculator while the code for the program was written in **C#**. The user has to put in the values of the estimated parameters and the calculator will give the index value within a fraction of seconds without any complex calculation to be done by the user.

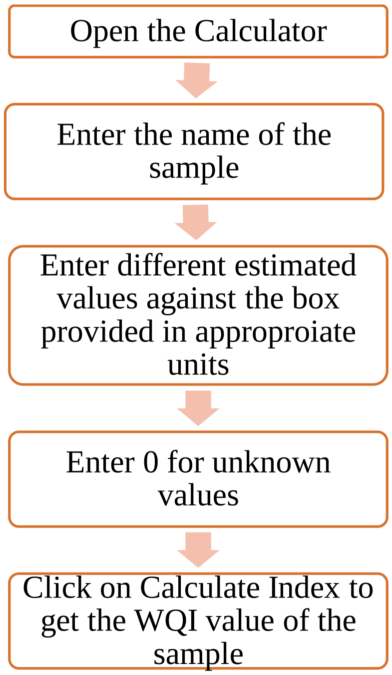
Algorithm

1. The values of unit weights of different parameters (Wn) and the standard permissible limits of the parameters (Sn) are preloaded into the program.
2. The user inputs the estimated parameters from which the Quality Rating or Sub-index of parameters are calculated. A part of the code used for calculation is given below

```
if (v[i] != 0)
{
    q[i] = w[i] * 100 * v[i] / s[i];
    wqSum += q[i];
}
```

3. The calculated index value is converted into a string before displaying it on the screen.
4. The unknown parameters must be input as **0**. The weightage of these parameters will not be considered for calculation.
5. There is also a text box provided to enter the name of the sample and a results table comparing WQI values to water quality is present on the calculator screen itself.
6. All the calculation procedures, standard permissible limits and the weightage values are taken from the proposed weighted arithmetic method of WQI calculation by **Brown et al. (1972)**.

Procedure



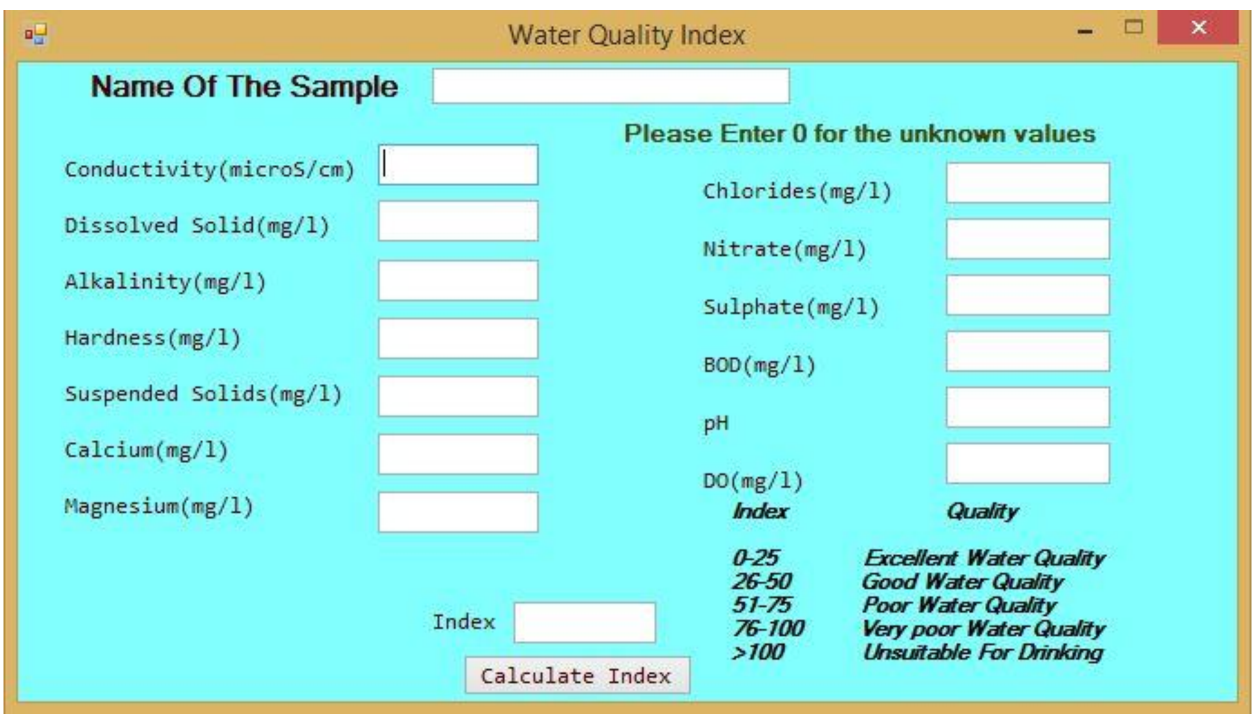




Fig 5.1: Screenshot of the Calculator

Water Quality Index was calculated for each sample using the designed calculator. The results are as follows:

**Sample-1 = 26.404** → **Good Water Quality**

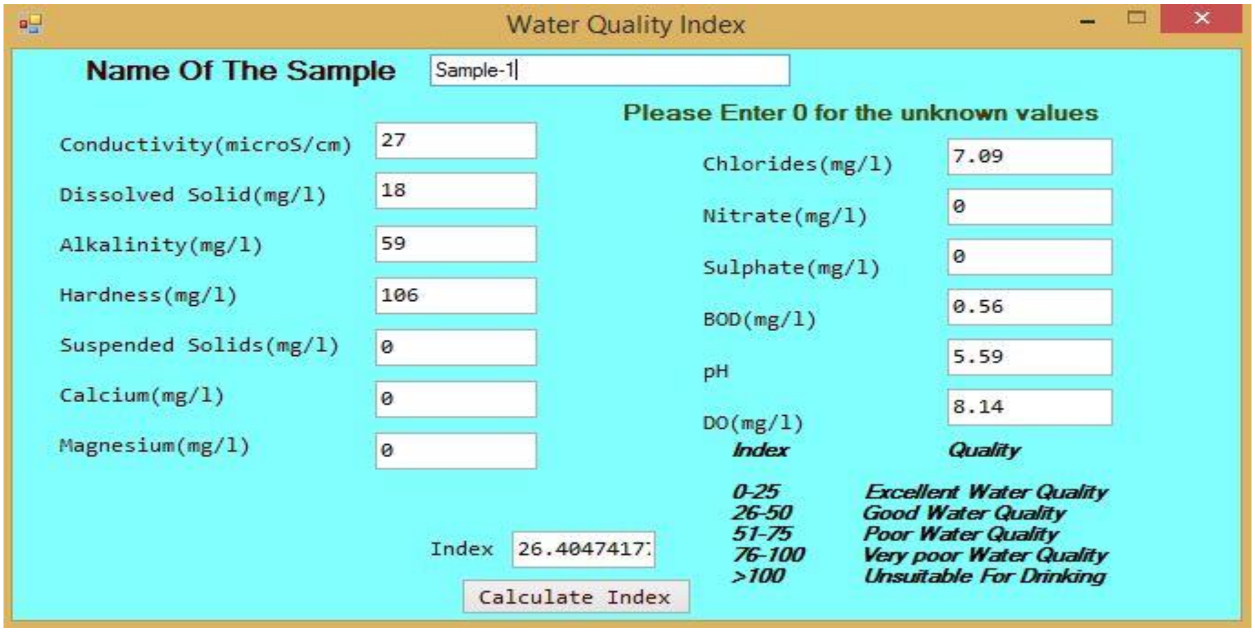



Fig 5.2: WQI of Sample-1

**Sample-2 = 25.61** → **Good Water Quality**

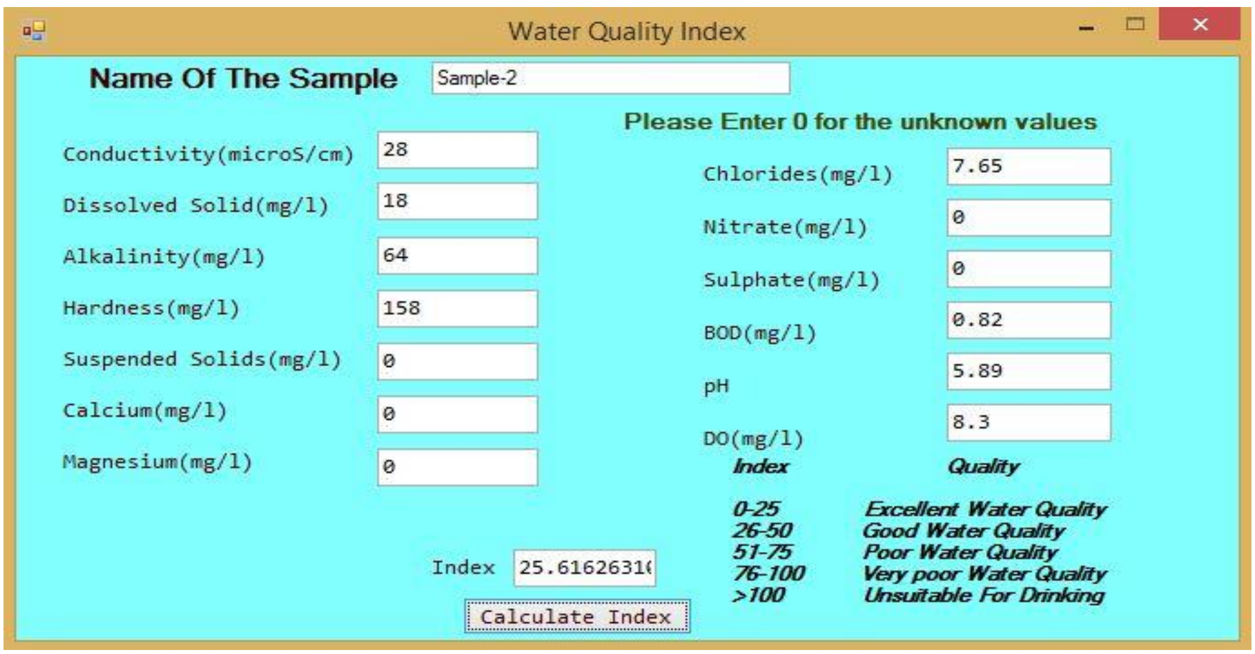



Fig 5.3: WQI of Sample-2

**Sample -3 = 29.76 → Good Water Quality**

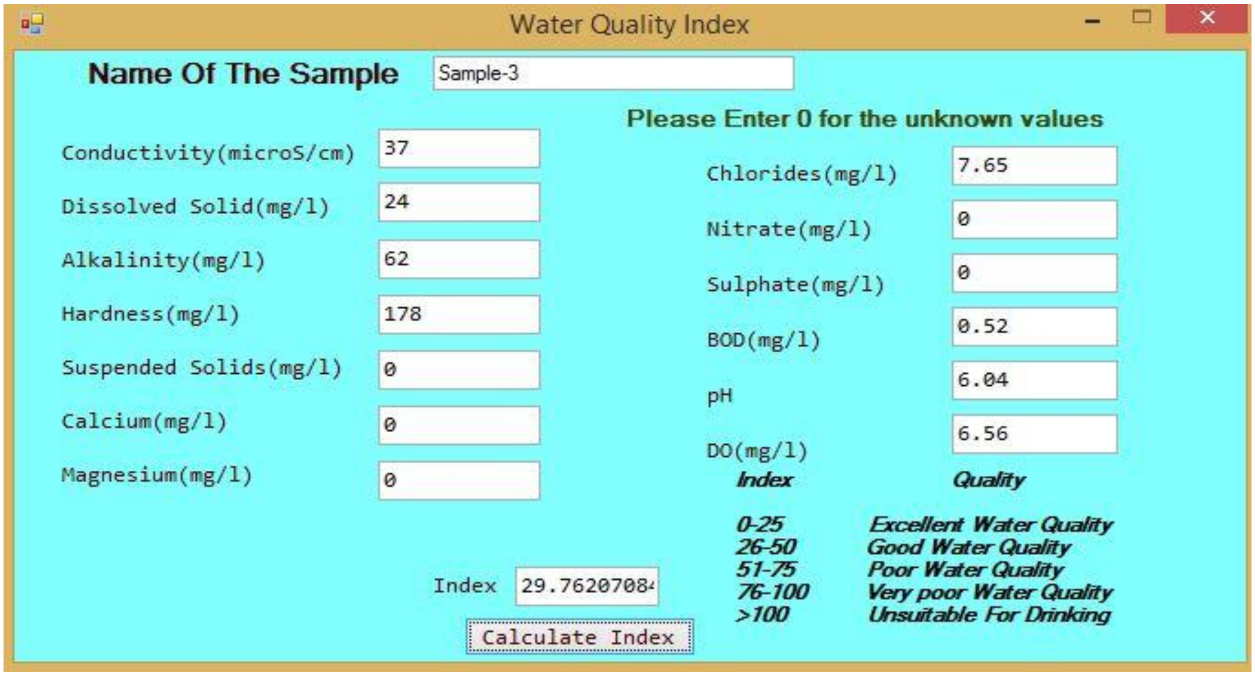



Fig 5.4: WQI of Sample-3

**Sample-4 = 24.925 → Excellent Water Quality**

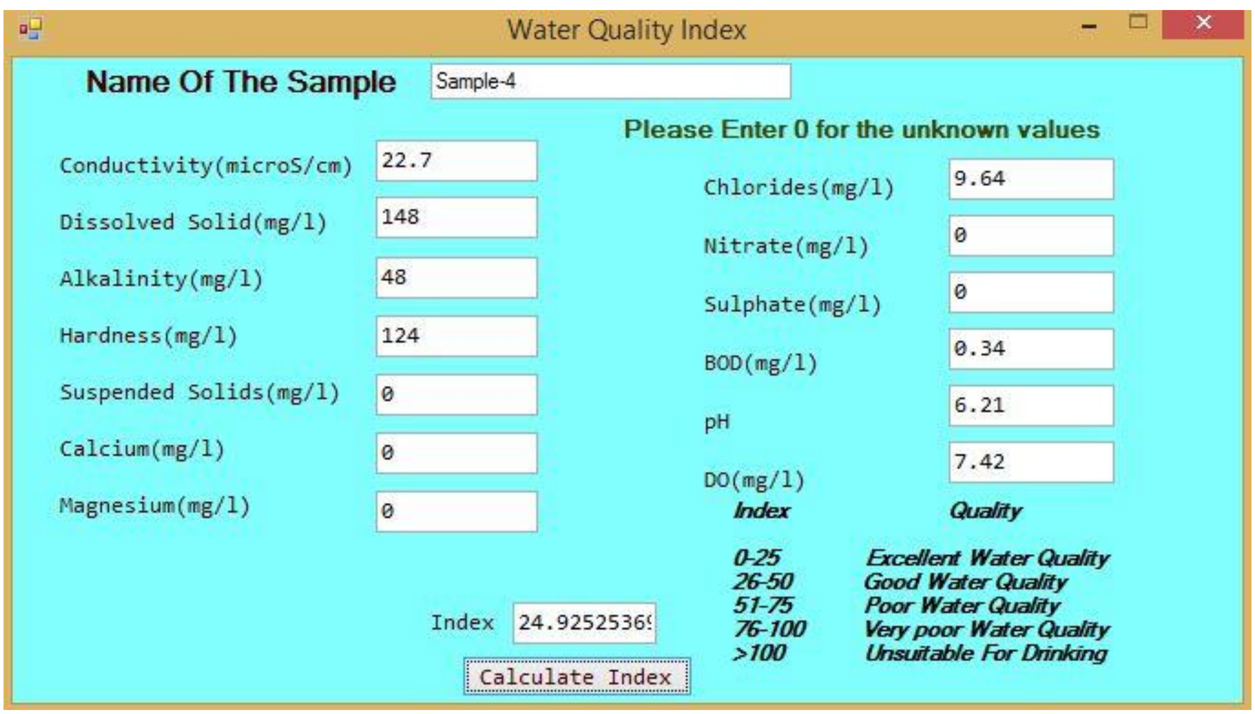



Fig 5.5: WQI of Sample-4

**Sample-5 = 17.660** → **Excellent Water Quality**

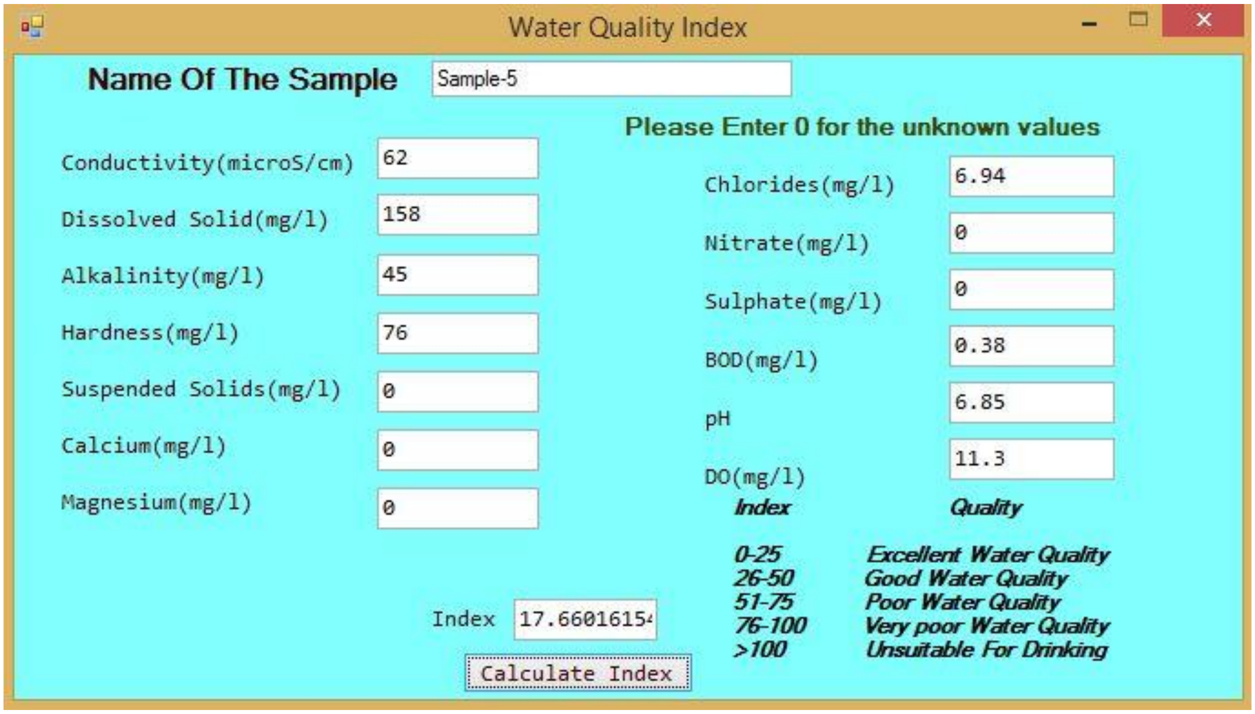



Fig 5.6: WQI of Sample-5

# CHAPTER-6

# DISCUSSIONS AND CONCLUSION

# 6. DISCUSSIONS AND CONCLUSION

## 6.1 *Discussions*

Mining being extractive in nature always has adverse effects on the environment. It is necessary for the mine management to look after the impacts that the mining activities put on the environment and try their best to curb these impacts as much as possible. Recent technological developments and changes in rules and regulations have helped reduce accidents in mines and also make mining ecofriendly.

As it can be seen from the results, most of the parameters are found within the permissible limits. There are a few deviations which must be taken care of.

- The turbidity value of all the samples except Sample-3 was found to be high. Sample-4 and 5 have a turbidity value greater than the permissible limits. These being tap waters and used for daily usage, must be properly treated to reduce the turbidity.
- The pH of all the samples are below 7. While the permissible limits for pH is 6.5-8.5, only sample-5 is found to be within the limits while all others are below 6.5. The acidic nature of the water can lead to acid mine drainage and dissolve more and more metals increasing the metal content of water.
- The metal ion concentration in all the samples were found to be below permissible limits except for Chromium which was found to be of more than the permissible limit in sample-1, 2 and 3. Sample-3 being closer to an iron ore mine also showed high iron content in it which was found to be more than the permissible limit.

Table 6.1: WQI of different samples

| Sample | WQI | Quality |
|---|---|---|
| **1** | 26.69 | Good |
| **2** | 25.616 | Good |
| **3** | 29.76 | Good |
| **4** | 24.925 | Excellent |
| **5** | 17.66 | Excellent |

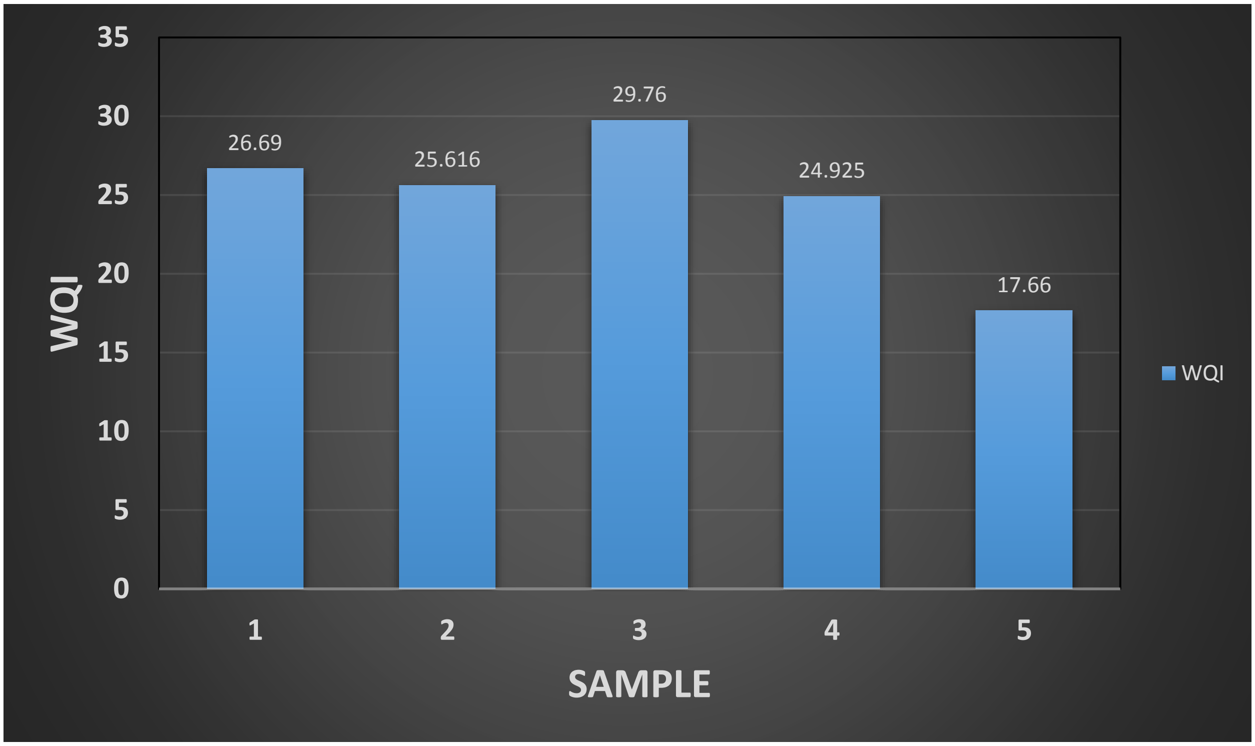
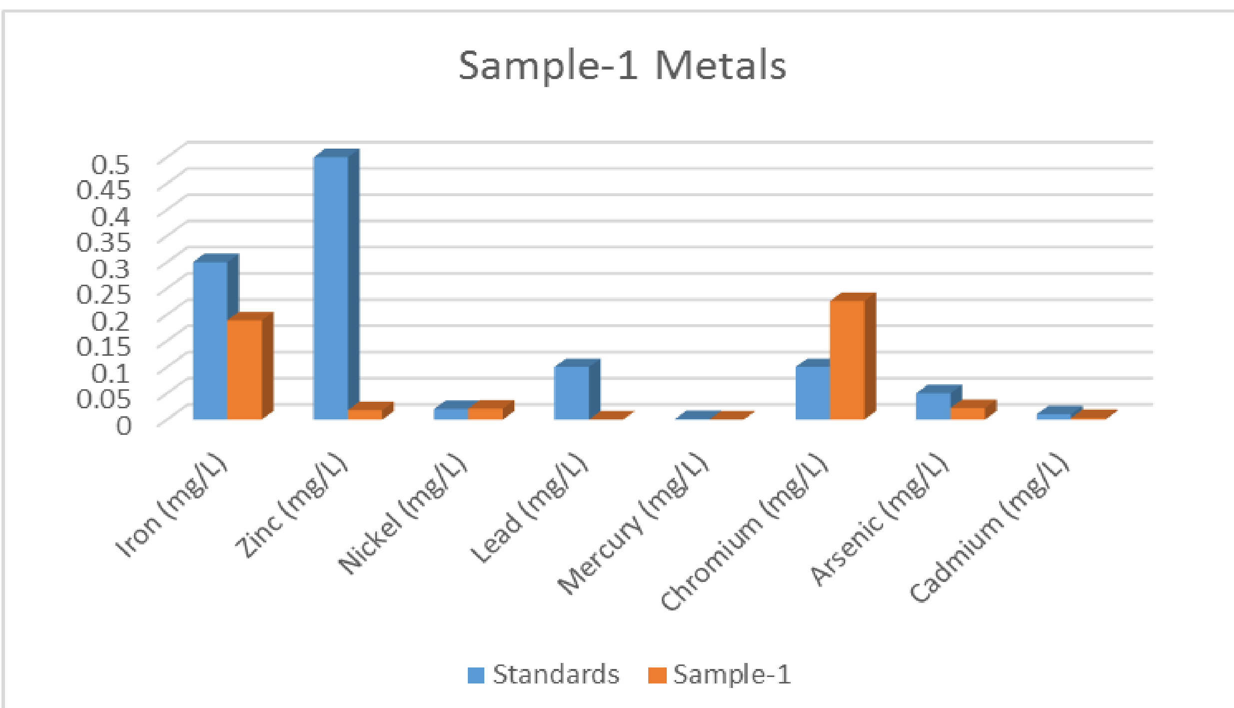
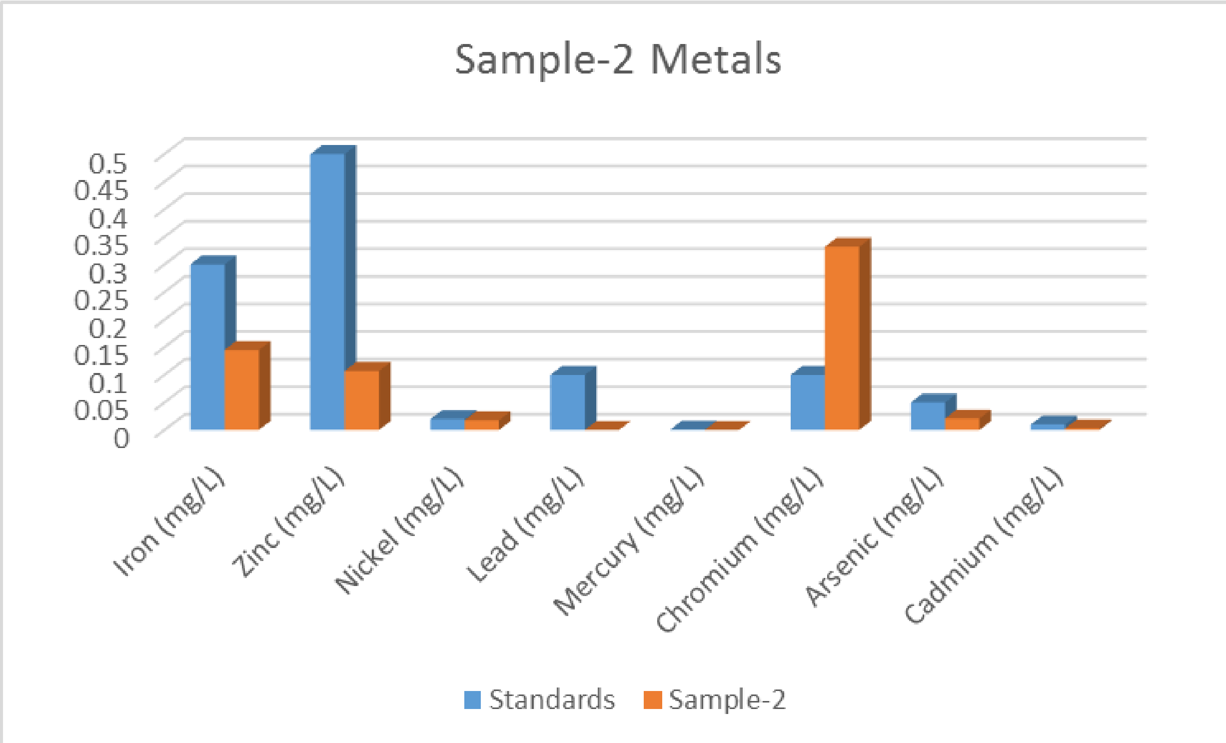
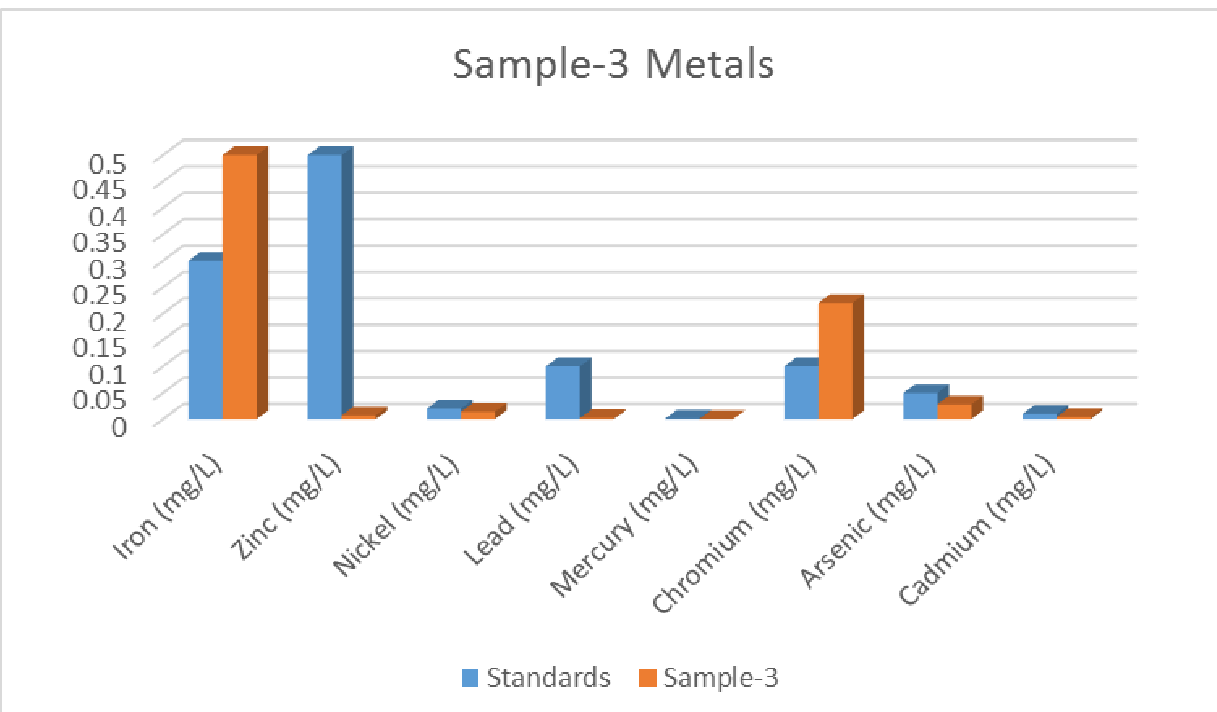
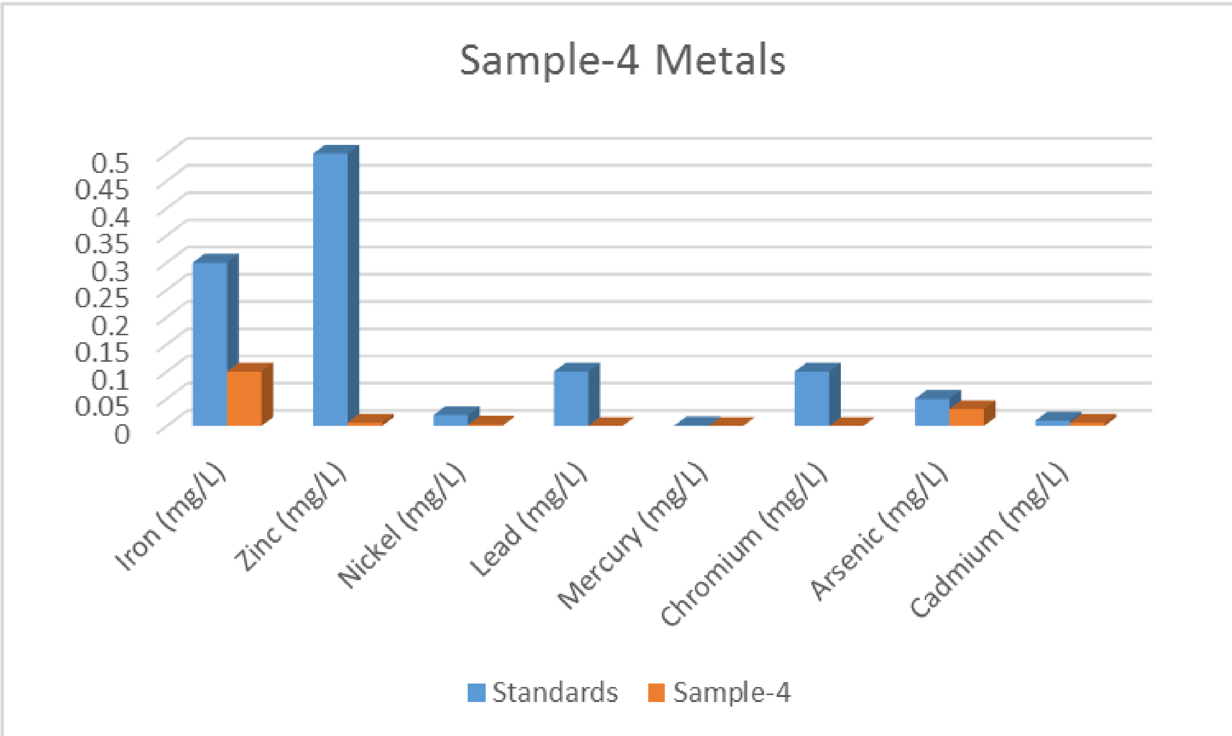



Fig 6.1: Comparison of WQI of all the samples

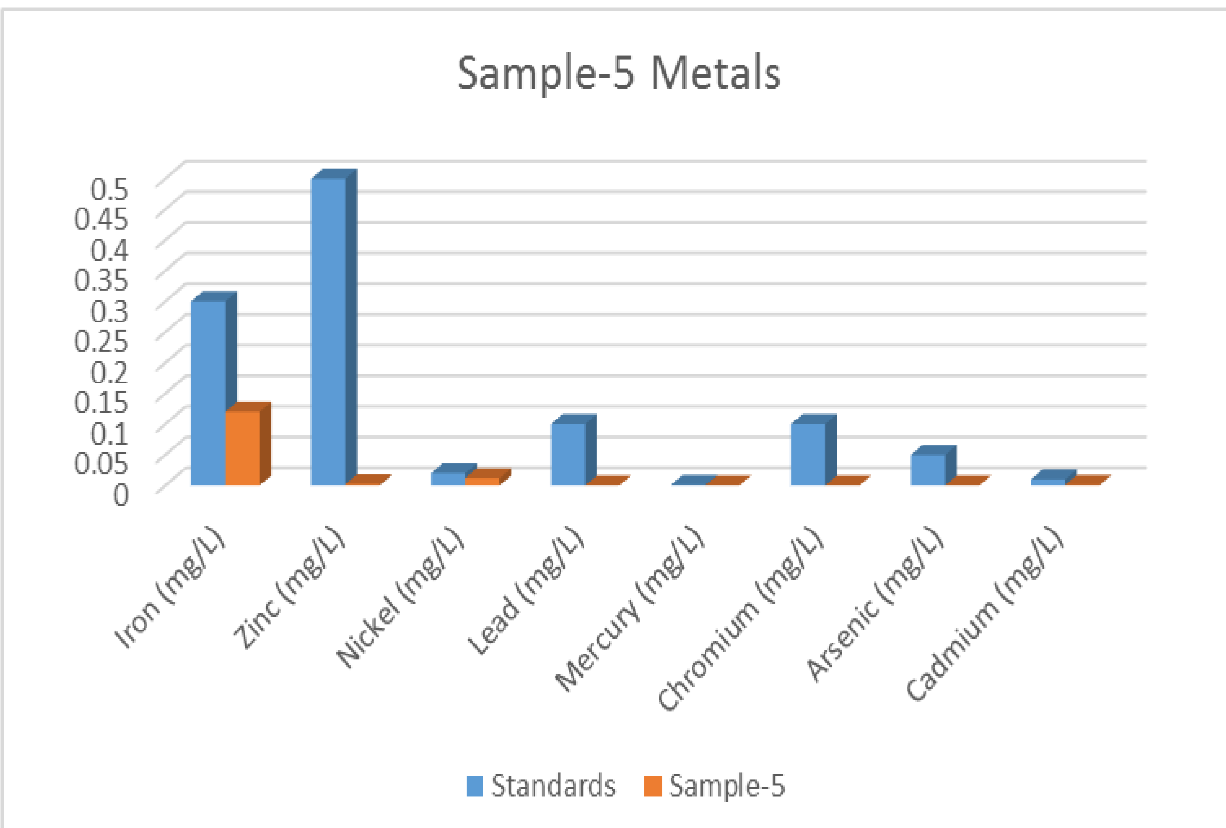



Sample-2 Metals
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Iron (mg/L)
Zinc (mg/L)
Nickel (mg/L)
Lead (mg/L)
Mercury (mg/L)
Chromium (mg/L)
Arsenic (mg/L)
Cadmium (mg/L)
Standards
Sample-2


Sample-3 Metals
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Iron (mg/L)
Zinc (mg/L)
Nickel (mg/L)
Lead (mg/L)
Mercury (mg/L)
Chromium (mg/L)
Arsenic (mg/L)
Cadmium (mg/L)
Standards
Sample-3



Sample-4 Metals
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Iron (mg/L)
Zinc (mg/L)
Nickel (mg/L)
Lead (mg/L)
Mercury (mg/L)
Chromium (mg/L)
Arsenic (mg/L)
Cadmium (mg/L)
Standards
Sample-4

Sample-5 Metals
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Iron (mg/L)
Zinc (mg/L)
Nickel (mg/L)
Lead (mg/L)
Mercury (mg/L)
Chromium (mg/L)
Arsenic (mg/L)
Cadmium (mg/L)
Standards
Sample-5

### *6.2 Conclusion*

The mine management has done a good job at keeping the concentration of most parameters within the limits. Both the tap water sample were of excellent water quality whereas the surface water samples were found to be of good water quality. However, they have to look after their methodologies as some of the parameters are still outside the permissible limit. All the water samples were found to be acidic which may be due to acid mine drainage. Proper measures must be taken to curb this. Chromium and iron content were also found to be high at some places. Water must be properly treated before allowing it to drain into rivers. Poisonous metals like Mercury, Lead, Arsenic and Cadmium were found at very low concentrations, some even below the detection levels which is a good sign for water quality. For proper management of water pollution, recycling of decanted effluent can be adopted for iron ore beneficiation plants. It will cause less consumption of raw water and less surface water pollution due to less discharge in the natural bodies.

It is clear from the results that mining activities have resulted in some environmental anomalies particularly in surrounding water sources. Low pH, high chromium and iron content are some irregularities to support this. There is a need of improvement in environment monitoring process of the mine to avoid such incongruities and help build a safe and clean environment

# CHAPTER-7

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# 7. REFERENCES

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